10.5 P Loads in Illinois River Watershed Streams and Rivers Assuming No Historic or Current Poultry Operations of the Defendants

P loads to Lake Tenkiller would be more than 275,000 lbs less than current levels (less than ½ of current levels) if poultry waste had never been disposed of in the IRW. It would take approximately 100 years of cessation of poultry waste application to return P loads in the IRW to what they would have been if no poultry waste land application had occurred.

Figures 10.25-10.30 show the P loads at the three gauging stations (Tahlequah, Baron Fork at Eldon and Caney Creek) assuming no historic or current poultry operations in the IRW. This assumes no poultry industry and therefore no poultry waste application in the IRW (e.g., no poultry waste application ever). It also assumes present (2003 and later) WWTP P loads continuing into the future. This will show the present and future state of P loads in the IRW surface waters assuming the defendants poultry operations never existed.

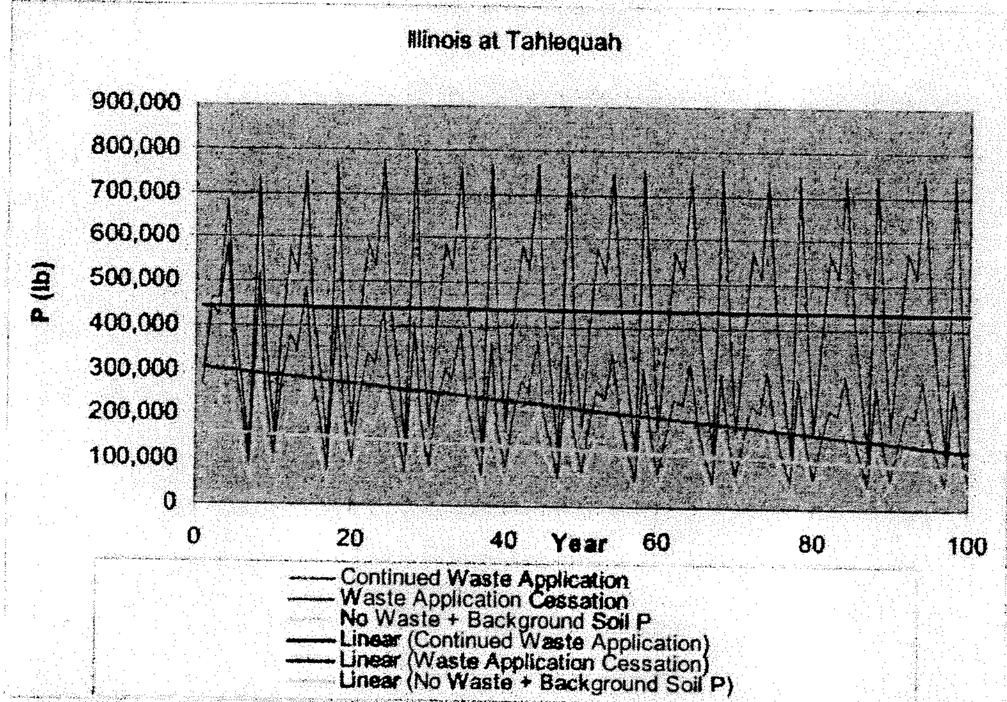

Figure 10.25. P Loads at Tahlequah for Background Soil P Levels with No Poultry Waste Application in the IRW.

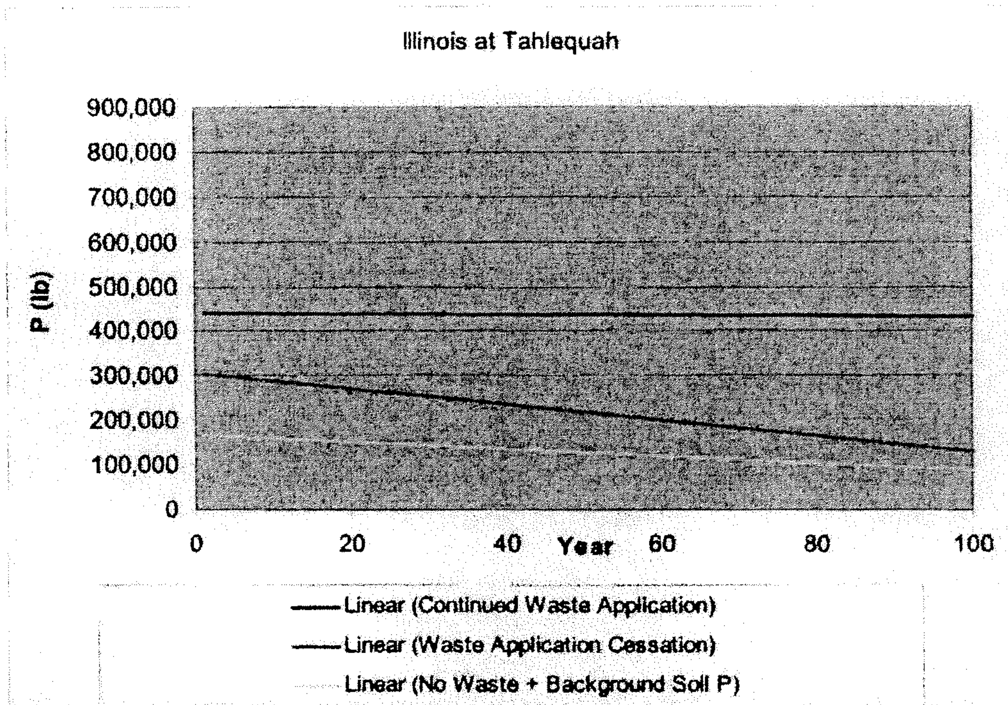

Figure 10.26. P Load Trend at Tahlequah for Background Soil P Levels with No Poultry Waste Application in the IRW.

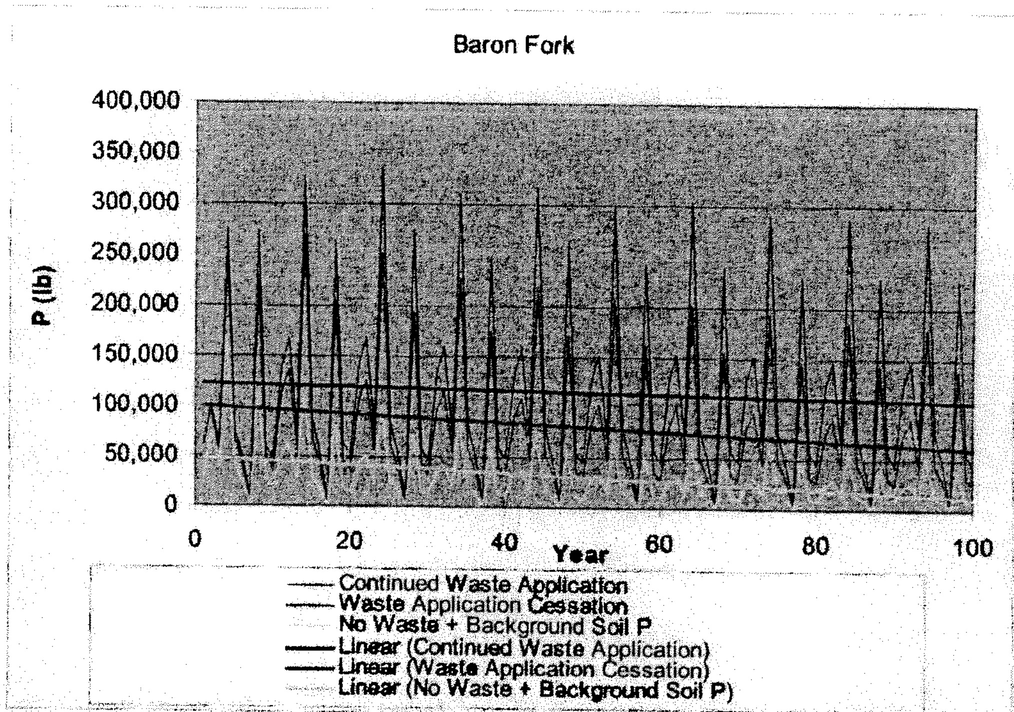

Figure 10.27. P Loads at Baron Fork near Eldon for Background Soil P Levels with No Poultry Waste Application in the IRW.

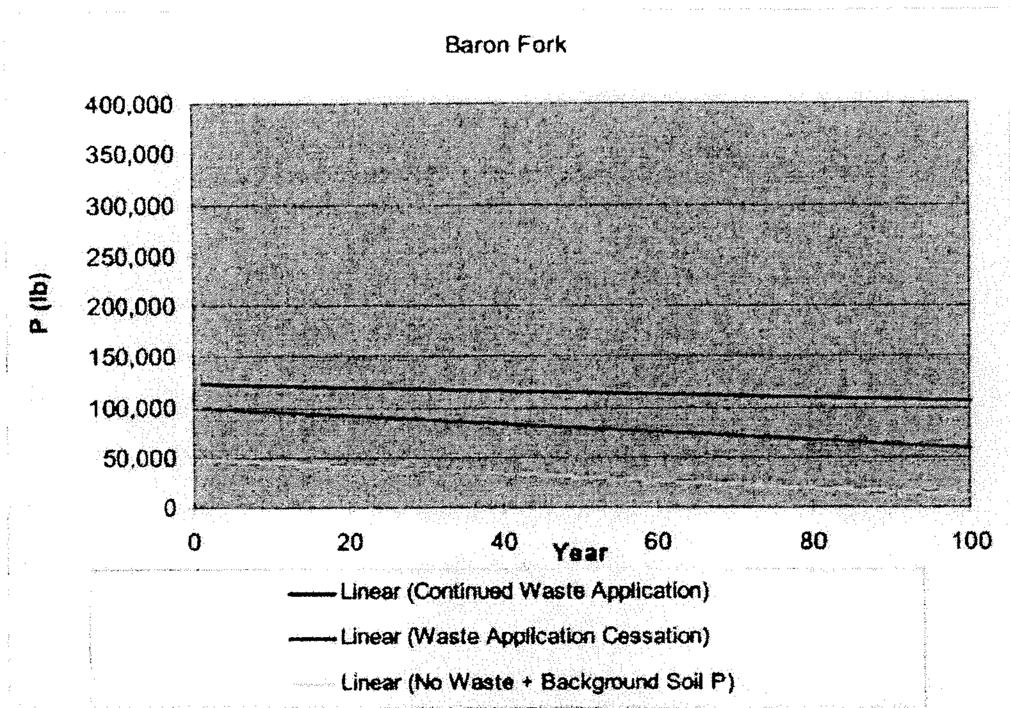

Figure 10.28. P Load Trend at Baron Fork near Eldon for Background Soil P Levels with No Poultry Waste Application in the IRW.

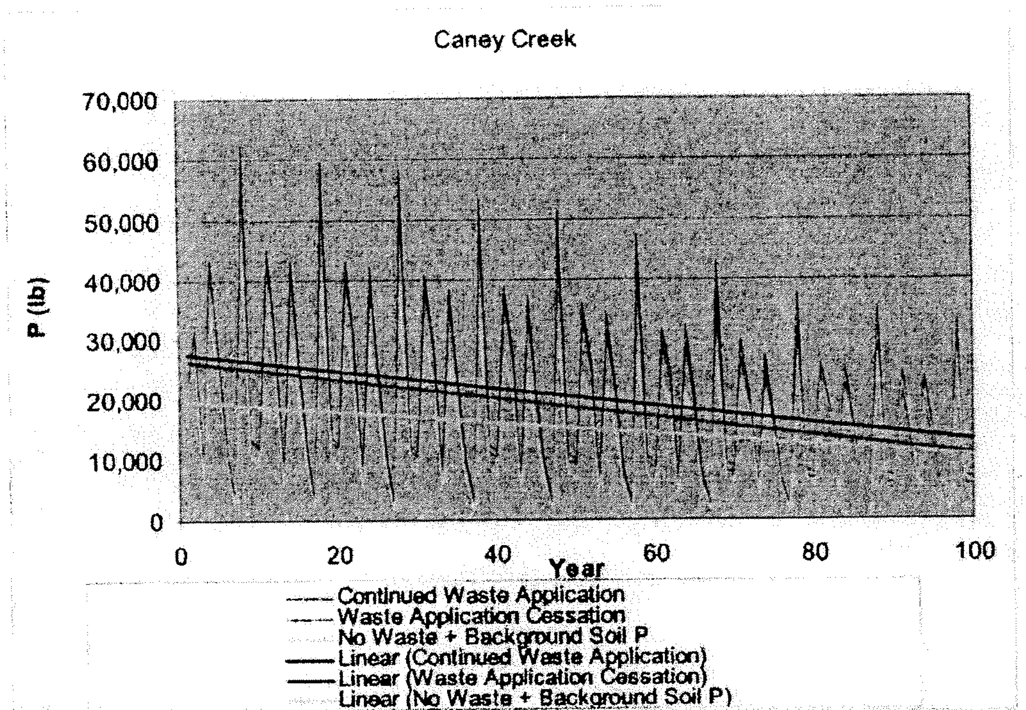

Figure 10.29. P Loads at Caney Creek for Background Soil P Levels with No Poultry Waste Application in the IRW.

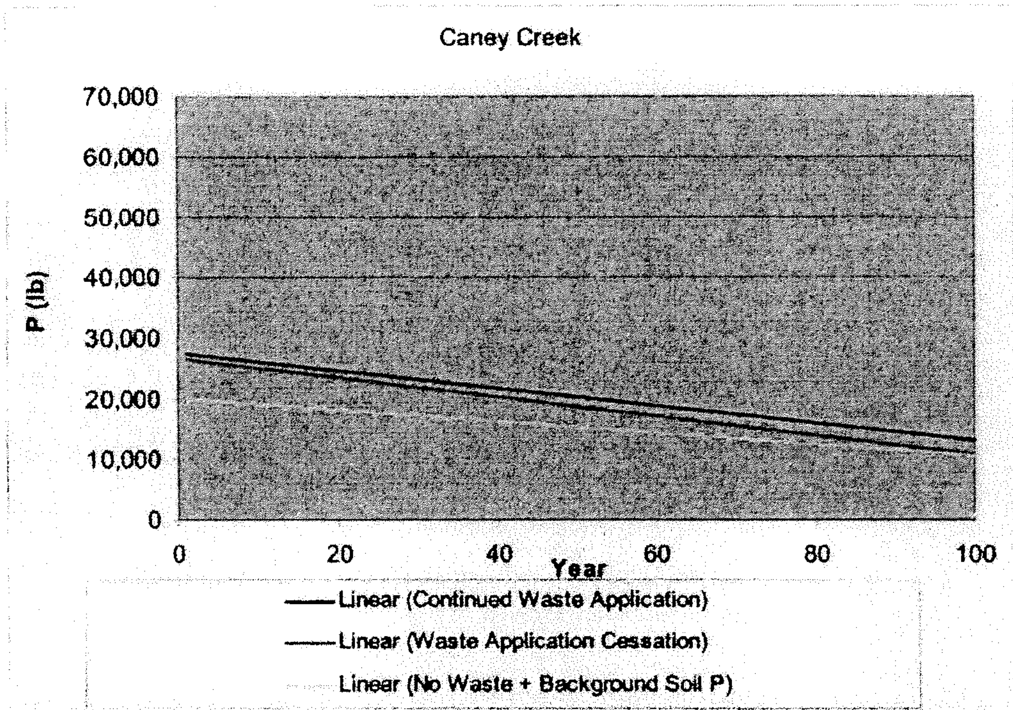

Figure 10.30. P Load Trend at Caney Creek for Background Soil P Levels with No Poultry Waste Application in the IRW.

The P loads for this scenario at Tahlequah indicate P loads would be substantially less (more than 275,000 lbs annually) than those for continued poultry waste application. The P loads for the background scenario would also remain approximately 150,000 lbs annually greater than poultry waste spreading cessation, narrowing to about 50,000 lbs annually after 100 years. This is due to the vast amount of P that has accumulated in IRW soils due to excessive poultry waste application (see Section 7. Phosphorus Mass Balance and see Johnson, 2008).

Differences between background P loads at Baron Fork near Eldon and continued poultry waste application would be approximately 75,000 lbs annually. The difference between background P loads and those with poultry waste application cessation would be approximately 50,000 lbs annually.

Differences in background P loads for the Caney Creek gauging location and continued poultry waste application would be small due to the limited poultry waste application in this watershed.

Table 10.10 summarizes the results for no historic or current poultry operations in the IRW and for poultry waste application cessation in the IRW. The P loads for no historic or current poultry operations in the IRW would decline over time due to P removal from the system (P loads to Lake Tenkiller and cattle). Even after 100 years, the waste cessation scenario indicates expected P loads to Lake Tenkiller would be greater than the P load for no historic or current poultry operations in the IRW (years 1-10). Thus, even after 100 years of poultry waste application cessation in the IRW, the elevated soil P levels due to historic poultry waste application would continue to contribute to P loads to IRW waters.

Table 10.10. P Loads to IRW Waters with No Poultry Waste Application and Total P Load to Lake Tenkiller for Poultry Waste Application Cessation. Weather Repeats Every 10 Years So Results Are Summarized in 10 Year Periods.

	P Load (lbs)				
Years	Tahlequah	Baron	Caney	No Application Total	Total (Cessation)
1-10	1,593,185	517,044	183,305	2,293,534	4,343,485
11-20	1,577,197	418,569	191,028	2,186,795	4,019,937
21-30	1,416,532	360,511	177,237	1,954,279	3,658,654
31-40	1,316,867	305,908	162,427	1,785,203	3,315,579
41-50	1,232,647	268,748	149,734	1,651,129	3,093,820
51-60	1,155,226	245,471	136,380	1,537,077	2,895,368
61-70	1,112,297	238,307	132,631	1,483,235	2,737,468
71-80	1,077,848	225,995	130,736	1,434,579	2,588,668
81-90	1,057,895	208,819	128,060	1,394,774	2,498,852
91-100	1,044,273	192,647	127,000	1,363,920	2,437,254

10.6 Historical P Loads in Illinois River Watershed Streams and Rivers

P loads to Lake Tenkiller since 1954 have increased at approximately 10,000 lbs per year. Poultry waste application in the IRW is responsible for approximately 6,600 lbs of this increase each year.

P loads to the 3 gauging stations (Tahlequah, Baron Fork, and Caney Creek) were modeled using the same approach that has been used for modeling of results presented in prior sections. Soil P levels were assumed to be equivalent to current levels in Sequoyah County which would be considered equivalent to soil P levels for the entire watershed in 1950. WWTP P discharges were included as described in the WWTP section for 1950 through 1999 (Table 6.3). Poultry P applications to pastures in the IRW were based on historical poultry production in the watershed (Section 7).

Figures 10.31-10.33 show the modeled P loads from the IRW from 1950-1999. The trend line at the Tahlequah indicates P loads increase approximately 9,200 lbs/year and at Baron Fork by approximately 770 lbs/year. The Caney Creek watershed showed little change in P loads over this 50 year period, since its pastures received little poultry waste over this period.

Stow et al. (2001) computed historical nutrient loads in a watershed using a similar approach. Nutrient inputs to the watershed were computed for a more than 100 year period. WWTP nutrient inputs were computed using a similar approach as used within this report. Using the nutrient inputs and historical nutrient trends in observed river water, nutrient concentrations were computed.

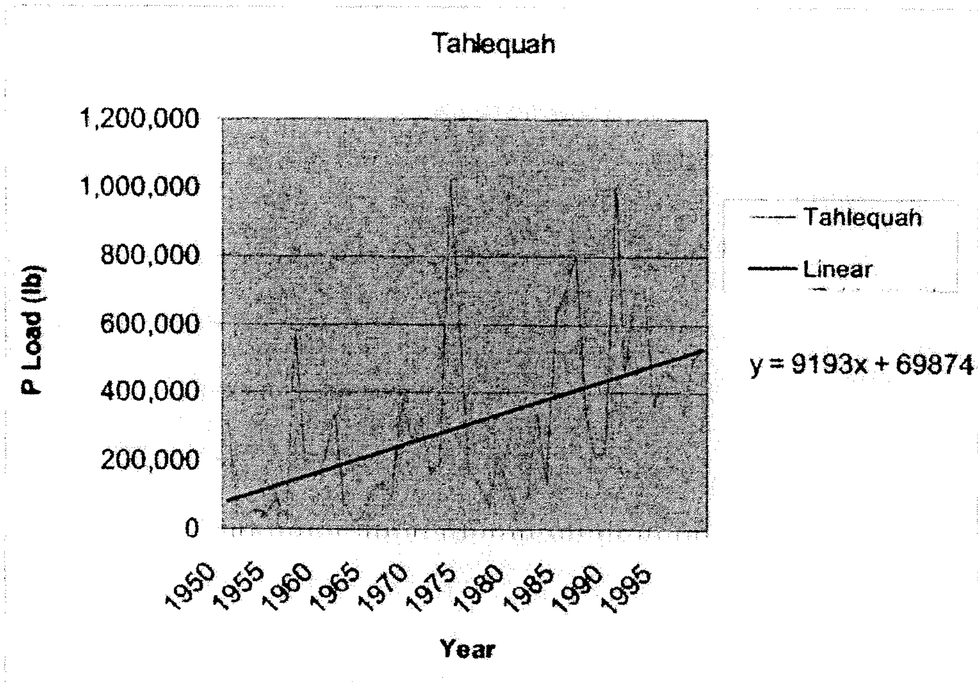

Figure 10.31. Modeled P Load and P Load Trend Line to Tahlequah from 1950 to 1999 Using Observed WWTP P Discharges and IRW Poultry Production

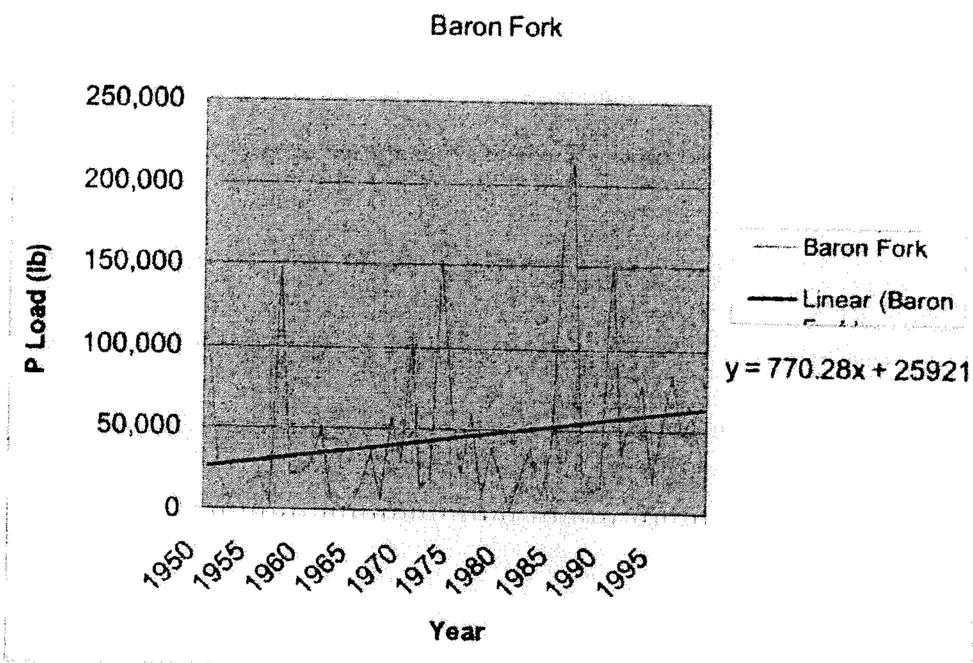

Figure 10.32. Modeled P Load and P Load Trend Line to Baron Fork near Eldon from 1950 to 1999 Using Observed WWTP P Discharges and IRW Poultry Production

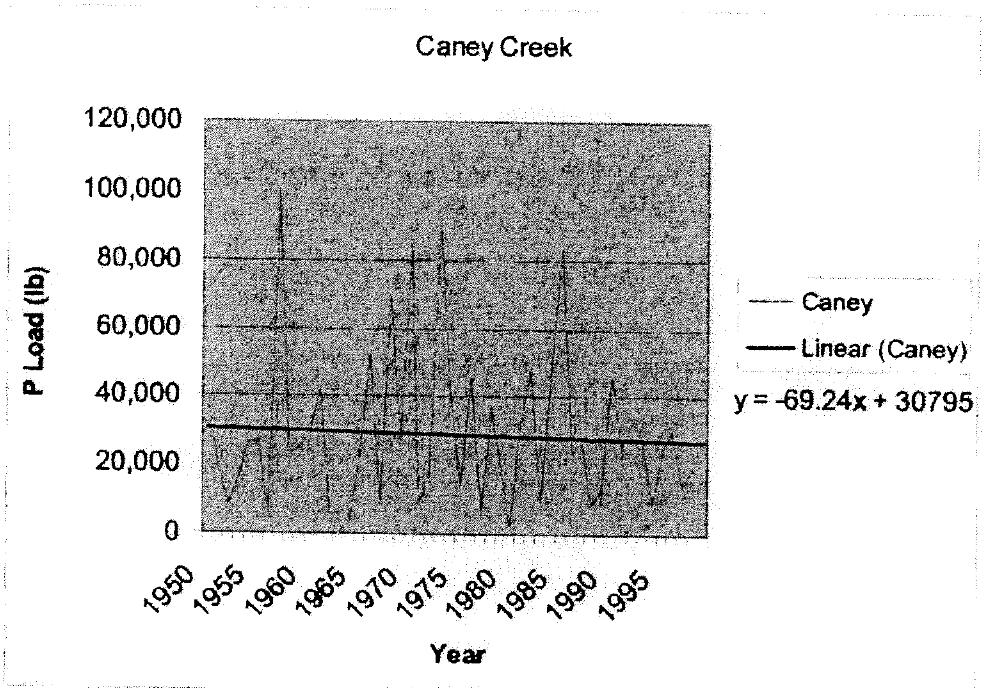

Figure 10.33. Modeled P Load and P Load Trend Line to Caney Creek from 1950 to 1999 Using Observed WWTP P Discharges and IRW Poultry Production

The NPS P loads from 1950 through 1999 are shown in Figures 10.34-10.36 for Tahlequah, Baron Fork at Eldon and Caney Creek. The WWTP P loads were not included in the results shown in Figures 10.34-10.36. The trend lines indicate P loads increase 6,700 lbs annually due to NPS sources. Nearly all of the increased P load is attributable to poultry waste application in the IRW (see P inputs into the IRW as documented in the Mass Balance Analysis in Appendix B).

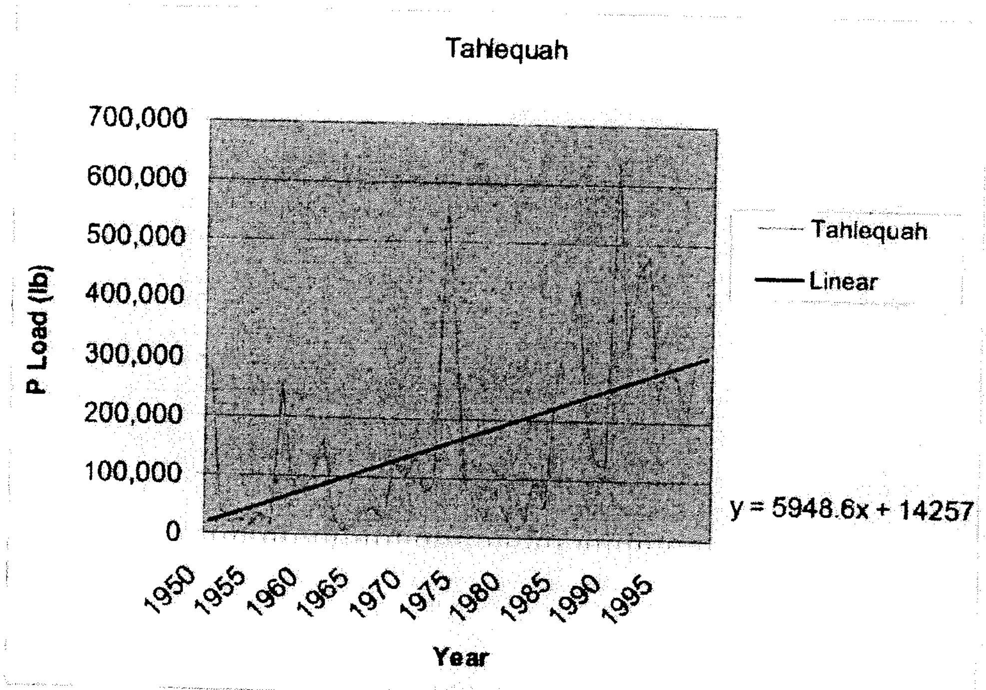

Figure 10.34. Modeled NPS P Load and NPS P Load Trend Line at Tahlequah from 1950 to 1999 Using IRW Poultry Production Data

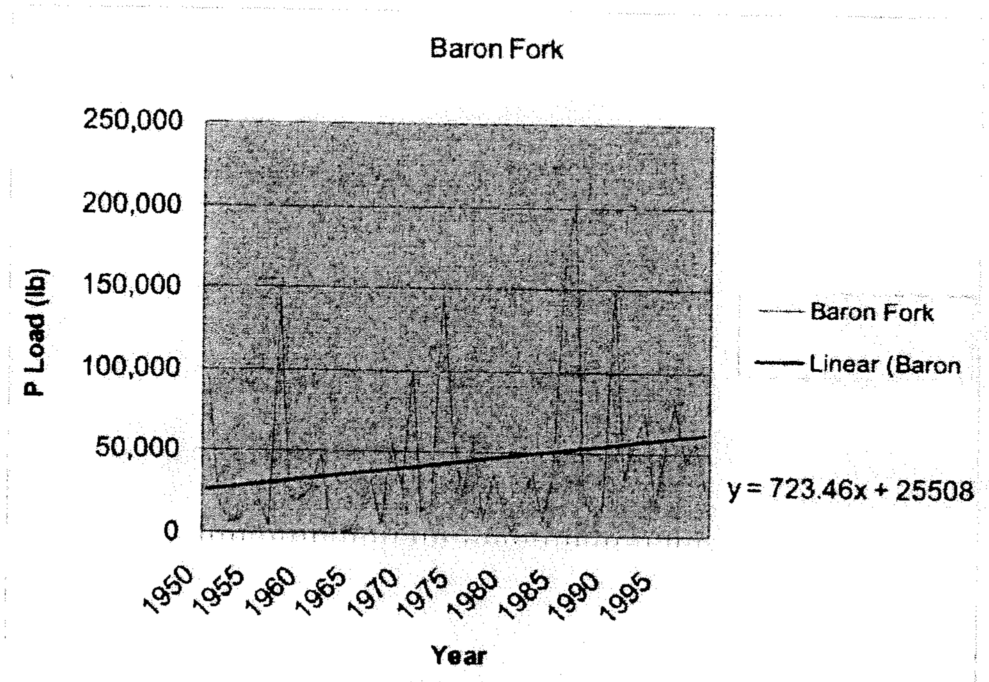

Figure 10.35. Modeled NPS P Load and NPS P Load Trend Line to Baron Fork Near Eldon from 1950 to 1999 Using IRW Poultry Production Data

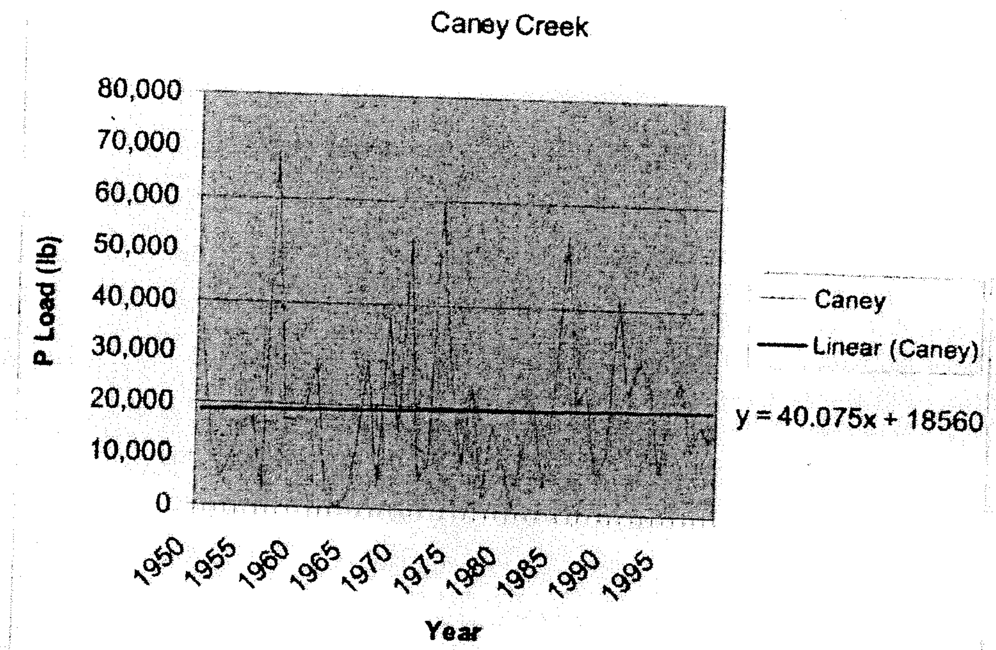

Figure 10.36. Modeled NPS P Load and NPS P Load Trend Line to Caney Creek from 1950 to 1999 Using IRW Poultry Production Data

Average annual historical P concentrations for March-June and July-September were computed for the Tahlequah and Baron Fork locations in support of Dr. Jan Stevens' analysis. Average concentrations were computed based on daily concentrations for each of the analyses periods. Figures 10.37 and 10.38 show P concentrations at Tahlequah for March-June and July-September, respectively. Average concentrations were computed based on daily concentrations for each of the analyses periods. Figures 10.39 and 10.40 show P concentrations at Baron Fork for March-June and July-September, respectively. The P concentration trends for these periods are similar to annual P load trends.

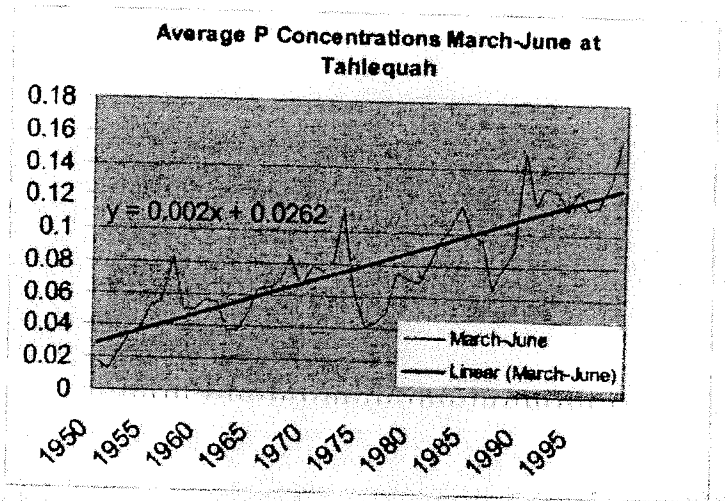

Figure 10.37. Average P Concentrations for March-June Annually at Tahlequah from 1950 Through 1999 Using IRW Poultry Production Data

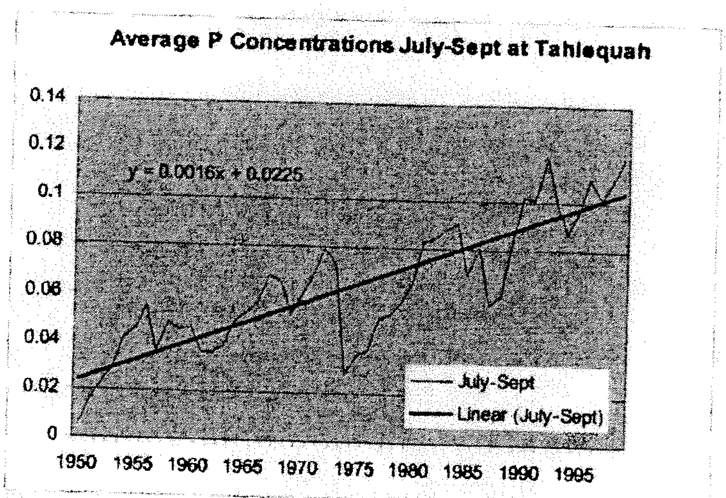

Figure 10.38. Average P Concentrations for July-September Annually at Tahlequah from 1950 Through 1999 Using IRW Poultry Production Data

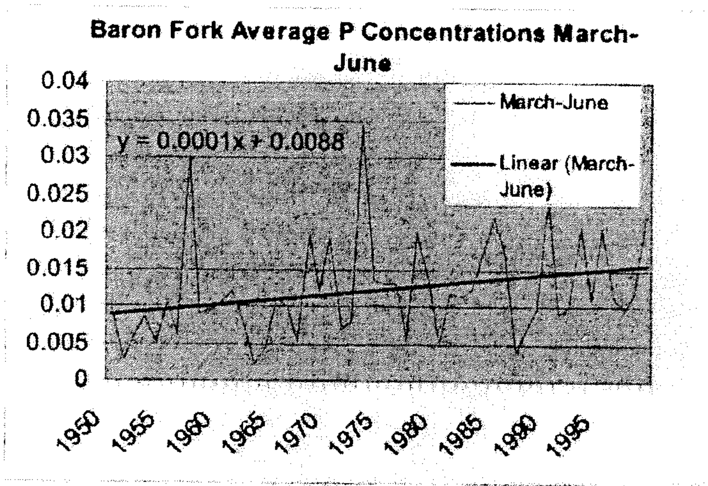

Figure 10.39. Average P Concentrations for March-June Annually at Baron Fork from 1950 Through 1999 Using IRW Poultry Production Data

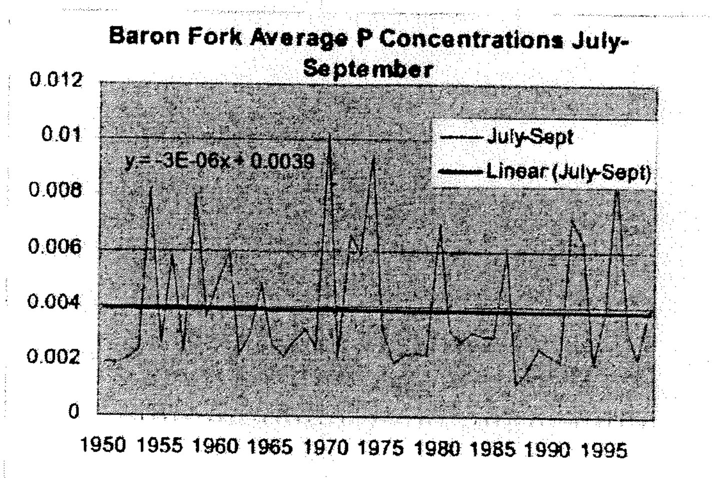

Figure 10.40. Average P Concentrations for July-September Annually at Baron Fork from 1950 Through 1999 Using IRW Poultry Production Data

10.7 Statistical Analysis of P Loads

A statistical analysis of the modeled P loads was conducted to determine if the P loads for the scenarios were statistically different. Both parametric (ANOVA) and nonparametric (Kruskal-Wallis Test) analyses were completed for each of the scenarios at each of the sites (Tahlequah, Baron Fork, and Caney).

For each location, boxplot exploratory data analysis (EDA) was used to gain insight of the distribution of the daily P losses. This was done to ensure that assumptions and constraints of Gaussian statistical procedures were not violated. For example, the validity of parametric tests such as Analysis of Variance (ANOVA) requires that the data follow a Gaussian distribution with constant variance (Montgomery, 2004). If the model assumptions of normality and constant variance are violated, then nonparametric testing procedures are usually more robust. However, in practice, an alternative approach to nonparametric tests involves the application of logarithmic transformation to the data; thereby, facilitating the use of parametric test for further analysis. This procedure stabilizes the variance while creating a distribution closer to normality. It is useful especially in cases where the data set have large or very small values. The data were log transformed for use with the parametric tests.

The ANOVA analyses and multiple comparison tests were generated using SAS/STAT® software, version 9.1.3 (SAS, 2004). The test statistics was based on the following hypothesis: H_0: $\tau_1 = \tau_2 = \tau_3 = \tau_4 = \tau_5 = \tau_6 = 0$ versus H_1: at least one treatment is not equal
where,

H_0 = null hypothesis
H_1 = alternative hypothesis
τ_1= effects of continue waste application
τ_2= effects of waste application cessation
τ_3= effects of growth
τ_4= effects of no waste ever
τ_5= effects of waste cessation and buffer along third order and above streams
τ_6= effects of waste cessation and buffers along all streams

Tukey multiple comparison indicates that P loads for each of the six scenarios for Tahlequah and Baron Fork were statistically different (Tables 10.11 and 10.12). For Caney Creek scenarios, the P loads for 'Waste Cessation + Buffer All' (waste application cessation and buffers along all streams and rivers) and 'No Waste Background P' (no poultry waste application ever in the watershed) were not significantly ($\alpha < 0.05$) different; however, all other P loads for Caney Creek scenarios were significantly different from each other (Table 10.13).

The statistical analyses indicate the continued growth in the poultry industry within the IRW and land application of poultry waste would provide the largest P loads, continued poultry waste application would provide the next largest P loads, and cessation of land application would provide the next largest loads. Cessation of waste application with buffers along third order streams would provide the next largest loads and waste application cessation with buffers along all streams would provide the next largest P loads. The lowest P loads occur for the case in which no poultry waste application was ever applied within the IRW.

Table 10.11. Statistical summary of phosphorus scenarios based on daily P output for Illinois River at Tahlequah

Treatment	N	Mean Daily P Load (lb)
Continue Waste Application	36525	543.69[a]
Waste Cessation	36525	270.00[b]
50 Year Growth	18300	876.26[c]
No Waste Background P	36525	156.44[d]
Waste Cessation + Buffer	36525	262.07[e]
Waste Cessation + Buffer All	36525	244.51[f]

Note: Means with the same letter are not significantly different at the 5% level.
N is number of observations (daily P loads)

Table 10.12. Statistical summary of phosphorus scenarios based on daily P output for Baron Fork near Eldon

Treatment	N	Mean Daily P Load (lb)
Continue Waste Application	36525	141.64[a]
Waste Cessation	36525	99.16[b]
50 Year Growth	18300	172.58[c]
No Waste Background P	36525	37.04[d]
Waste Cessation + Buffer	36525	93.00[e]
Waste Cessation + Buffer All	36525	82.46[f]

Note: Means with the same letter are not significantly different at the 5% level.
N is number of observations (daily P loads)

Table 10.13. Statistical summary of phosphorus scenarios based on daily P output for Caney Creek

Treatment	N	Mean Daily P Load (lb)
Continue Waste Application	36525	25.18[a]
Waste Cessation	36525	23.13[b]
50 Year Growth	18300	29.63[c]
No Waste Background P	36525	18.89[d]
Waste Cessation + Buffer	36525	21.86[e]
Waste Cessation + Buffer All	36525	19.06[d]

Note: Means with the same letter are not significantly different at the 5% level.
N is number of observations (daily P loads)

10.8 Allocation of P to Sources

Poultry waste land application in the IRW is a substantial contributor (45% between 1998 and 2006 and 59% between 2003 and 2006) to P loads to Lake Tenkiller, representing the largest P source. WWTP P loads are the second largest contributor to P loads to Lake Tenkiller. Poultry plant discharges to WWTP represent a significant portion of WWTP P loads.

The P contribution of each significant source was determined using the IRW modeling (Appendix D). The P allocation to each source is shown in Tables 10.14 and 10.15. P loads from poultry waste application within the IRW represents 45% of P loads to Lake Tenkiller between 1998 and 2006. Following a change in WWTP technology that reduced WWTP P discharges, poultry waste application in the IRW was responsible for 59% of P loads to Lake Tenkiller for years 2003-2006.

%

Table 10.14. IRW P Load Allocation to Sources

	WWTP	Forest	Crop	Urban	Pasture
1998-2006	30	1	< 1	7	62
2003-2006	15	1	< 1	7	76

Table 10.15. IRW P Load Allocation to Sources

	WWTP					Pasture		
	Poultry	Nonpoultry	Forest	Crop	Urban	Cattle Near Streams Only	Poultry Only	Swine, Dairy, Background
1998-2006	10	20	1	< 1	7	6	45	11
2003-2006	3	12	1	< 1	7	6	59	11

WWTP discharges are the second largest contributor of P loads representing 30% of P loads between 1998 and 2006 (Table 10.14). A portion of the WWTP P load is attributable to poultry processing discharge to the Springdale WWTP as described in Section 6. Poultry processing discharges released by the Springdale WWTP represent 10% of total P loads to Lake Tenkiller between 1998 and 2006 and 3% of P loads between 2003-2006 (Table 10.15).

Pasture with swine and dairy waste application and background P from pastures is the third largest P load to Lake Tenkiller (Tables 10.14 and 10.15). Runoff from urban areas is the fourth largest contributor at 7% of P loads (Tables 10.14 and 10.15). Cattle in and near streams contribute 6% of P. However, this is almost all poultry P because cattle only facilitate the transport of P (discussion of cattle contributions follows in the next section). Other sources of P loads are responsible for 1% or less of P loads to Lake Tenkiller.

These results are consistent with other reports for the IRW (Section 2 of this report) and with studies for similar watersheds. The Draft TMDL for the IRW and Lake Tenkiller (USEPA Region 6 and Department of Environmental Quality State of Oklahoma, 2001) identified pastures on which poultry waste is applied as being responsible for 56% of P to Lake Tenkiller. Smith et al. (1997) indicated more than 78% of P loads in the IRW were attributable to livestock waste. Storm and White (2003) estimated that poultry waste was responsible for more than 49% of P loads in the Eucha Spavinaw Watershed that has similar conditions to the IRW.

10.8.1 Contribution of Cattle in and Near Streams

Cattle in the IRW recycle P brought into the IRW to feed poultry that is excreted by poultry and land applied to pastures within the IRW. Although the P contribution of cattle is from poultry waste, cattle accelerate the movement of P into IRW streams and rivers when they excrete waste in and near IRW streams. Six percent of P loads to Lake Tenkiller result from cattle in and near IRW streams.

Cattle within the Illinois River Watershed are recycling poultry waste P that has been applied to pastures. For example, nutrients contained in beef cattle manure were ignored by Slaton et al. (2004) as they indicate "a large proportion of these nutrients are obtained from forage and deposited directly (i.e., recycled) to pastures during grazing rather than collected in lagoons or stockpiled from confined animal production facilities." Cattle largely consume grass from pastures and hay produced in the watershed, and thus P is not imported into the watershed in the form of cattle feed with the exception of a small amount of supplemental feed (Section 7 and Appendix B).

The amount of cattle waste and P in that waste were computed as described in Appendix E. Cattle in the IRW produce approximately 319,000 tons of waste annually (dry weight basis). This waste contains approximately 7.8 million lbs of P of which nearly all is recycled P from poultry waste, with the exception of 210,000 lbs of this P that is imported in cattle supplement (Section 7).

Cattle can accelerate the loading of P to surface water when they excrete waste in or near streams. The amount of P deposited by cattle in or near streams was calculated based on the length of streams, pasture near streams, average pasture sizes, cattle in the watershed, and excretion data for cattle in and near streams. Calculated P deposited by cattle in or near (within 10 meters) streams is up to 35,594 lbs/yr (6% of P loads to Tenkiller). Details of the calculations are provided in Appendix F.

10.8.2 Contribution of Septic Systems

The contributions of septic systems to P loads in the IRW are negligible based on the IRW Mass Balance analysis (Section 7 and Appendix B), analysis of P loads from sub-basins within the IRW for 2005 and 2006 (Olsen, 2008 and Appendix G), and analyses of IRW septic systems (e.g., Oklahoma Department of Environmental Quality (1997); Estimated Maximum Contribution of Phosphorus from Septic Systems, Illinois Basin, 1997).

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Rate of Compensation

Dr. Engel's rate of compensation for this case is $165 per hour.